Claims

What is claimed is:

1. A method for determining a property of a flowing fluid by nuclear magnetic resonance, comprising:

applying a static magnetic field to the flowing fluid;

acquiring a suite of nuclear magnetic resonance measurements on the flowing fluid using a pulse sequence comprising a spoiling pulse, a wait time, and an acquisition pulse sequence, wherein the suite of nuclear magnetic measurements have different values for the wait time; and

fitting the suite of nuclear magnetic resonance measurements to a forward model for responses of the flowing fluid to derive a parameter selected from a flow speed, longitudinal relaxation times of the flowing fluid, and a combination thereof.

2. The method of claim 1, wherein the acquisition pulse sequence comprises one selected from a spin-echo pulse sequence and a single pulse.

3. The method of claim 1, wherein the fitting is performed by inversion of the forward model.

4. The method of claim 1, further comprising estimating a viscosity of the flowing fluid based on the derived flow speed and a pressure drop across a selected length of a pipe in which the flowing fluid travels.

5. The method of claim 4, wherein the estimating is according to one selected from

$$\eta = \frac{\Delta P \cdot r_o^2}{8 \cdot v \cdot L} \quad \text{and} \quad \eta = K \frac{\Delta P}{v},$$

where η is the viscosity, v is an average speed of the flowing fluid, L is the selected length of the pipe, ΔP is the pressure drop over the selected length of the pipe, and r_o is a radius of the pipe, and K is an experimentally determined constant.

6. The method of claim 1, further comprising estimating a viscosity of the flowing fluid based on the derived longitudinal relaxation times and a gas-oil ratio of the flowing fluid.

7. The method of claim 6, wherein the estimating is according to:

$$\eta_o = \frac{k\,T}{T_{1,LM} \cdot f(GOR)}$$

where η_o is the viscosity, k is an empirically determined constant for the flowing fluid, T is a temperature in Kelvin, $T_{1,LM}$ is a logarithmic mean of the longitudinal relaxation times of the flowing fluid, and f(GOR) is an empirically determined function of the gas-oil ratio.

8. A method for determining a property of a flowing fluid by nuclear magnetic resonance, comprising:

applying a static magnetic field to the flowing fluid;

acquiring a suite of nuclear magnetic resonance measurements on the flowing fluid using a pulse sequence comprising a longitudinal relaxation investigation pulse sequence and an acquisition pulse sequence, wherein the suite of nuclear magnetic measurements have different values for a delay time within the longitudinal relaxation investigation pulse; and

fitting the suite of nuclear magnetic resonance measurements to a forward model for responses of the flowing fluid to derive a parameter selected from a flow speed, longitudinal relaxation times of the flowing fluid, and a combination thereof.

9. The method of claim 8, wherein the longitudinal-relaxation-investigation pulse comprises one selected from a inversion-recovery pulse sequence and a saturation-recovery pulse sequence.

10. The method of claim 8, wherein the acquisition pulse sequence comprises one selected from a spin-echo pulse sequence and a single pulse.

11. The method of claim 8, wherein the fitting is performed by inversion of the forward model.

12. The method of claim 8, further comprising estimating a viscosity of the flowing fluid based on the derived flow speed and a pressure drop across a selected length of a pipe in which the flowing fluid travels.

13. The method of claim 12, wherein the estimating is according to one selected from

$$\eta = \frac{\Delta P \cdot r_o^2}{8 \cdot v \cdot L} \quad \text{and} \quad \eta = K\frac{\Delta P}{v},$$

where η is the viscosity, v is an average speed of the flowing fluid, L is the selected length of the pipe, ΔP is the pressure drop over the selected length of the pipe, and r_o is a radius of the pipe, and K is an experimentally determined constant.

14. The method of claim 8, further comprising estimating a viscosity of the flowing fluid based on the derived longitudinal relaxation times and a gas-oil ratio of the flowing fluid.

15. The method of claim 14, wherein the estimating is according to:

$$\eta_o = \frac{k\,T}{T_{1,LM} \cdot f(GOR)}$$

where η_o is the viscosity, k is an empirically determined constant for the flowing fluid, T is a temperature in Kelvin, $T_{1,LM}$ is a logarithmic mean of the longitudinal relaxation times of the flowing fluid, and f(GOR) is an empirically determined function of the gas-oil ratio.

16. A method for monitoring contamination in a flowing fluid being withdrawn into a formation fluid testing tool using nuclear magnetic resonance, comprising:

applying a static magnetic field to the flowing fluid;

acquiring a suite of nuclear magnetic resonance measurements of the flowing fluid using a pulse sequence comprising a spoiling pulse, a wait time, and an acquisition pulse sequence, wherein the suite of nuclear magnetic measurements have different values for the wait time;

fitting the suite of nuclear magnetic resonance measurements to a forward model for responses of the flowing fluid to derive a property of the flowing fluid; and

monitoring a level of contamination in the flowing fluid based on the derived property of the flowing fluid.

17. The method of claim 16, wherein the property of the flowing fluid comprises one selected from a distribution of longitudinal relaxation times, a logarithmic mean of longitudinal relaxation times, and a combination thereof.

18. The method of claim 16, wherein the property of the flowing fluid is a viscosity.

19. A nuclear magnetic resonance apparatus, comprising:

a flow pipe including a prepolarization section and an investigation section, wherein the prepolarization section is upstream of the investigation section;

a magnet disposed around the flow pipe for creating a static magnetic field covering the prepolarization section and the investigation section;

an antenna disposed around the flow pipe at the investigation section for generating an oscillating magnetic field having a magnetic dipole substantially perpendicular to a magnetic dipole of the static magnetic field, and for receiving a nuclear magnetic resonance signal; and

a circuitry for controlling generation of the oscillating magnetic field and reception of the nuclear magnetic resonance signal by the antenna.

20. The apparatus of claim 19, wherein the circuitry includes a program having instructions for acquiring a suite of nuclear magnetic resonance measurements of a flowing fluid using a pulse sequence comprising a spoiling pulse, a wait time, and an acquisition pulse sequence.

21. The apparatus of claim 20, wherein the acquisition pulse sequence comprises one selected from a spin-echo pulse sequence and a single pulse.

22. The apparatus of claim 20, wherein the program further comprises instructions for fitting the suite of nuclear magnetic resonance measurements to a forward model for responses of a flowing fluid to derive a parameter selected from a flow speed, longitudinal relaxation times of the flowing fluid, and a combination thereof.

23. The apparatus of claim 22, wherein the fitting is performed by inversion of the forward model.

24. The apparatus of claim 22, wherein the program further comprising instructions for estimating a viscosity of the flowing fluid based on the derived flow speed or the derived longitudinal relaxation times.